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There exists a need by a large worldwide market for greatly improved small scale (1 to 20 MWe per unit) biomass-fueled power plants. These power plants will significantly increase the efficiency of generating electric power from wood and bagasse as well as convert non-traditional fuel sources such as rice hulls, animal manure, cotton gin trash, straws, and grasses to electricity. Advancing the technology of biomass-fueled power plants will greatly expand the use of this environmentally friendly sustainable 24 hr-per-day source of electrical power for industry and communities worldwide. This paper briefly describes the status of a biomass-fueled power plant under development by Cratech, Inc.

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DEVELOPMENT OF A NEW GENERATION OF SMALL SCALE BIOMASS-FUELED ELECTRIC GENERATING POWER PLANTS

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Abstract

There exists a need by a large worldwide market for greatly improved small scale (1 to 20 MWe per unit) biomass-fueled power plants. These power plants will significantly increase the efficiency of generating electric power from wood and bagasse as well as convert non-traditional fuel sources such as rice hulls, animal manure, cotton gin trash, straws, and grasses to electricity. Advancing the technology of biomass-fueled power plants will greatly expand the use of this environmentally friendly sustainable 24 hr-per-day source of electrical power for industry and communities worldwide. This paper briefly describes the status of a biomass-fueled power plant under development by Cratech, Inc.

"This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication."

Introduction

Responsibly using biomass as a fuel source in any power producing system places the user in the natural biological cycle; therefore, the user can produce sustainable power. A well managed and properly designed biomass power system releases little or no unnatural substances into the environment. As is the case with many natural biological systems, carbon dioxide will be produced but with zero net increase in quantity. Advancing the technology of biomass-fueled power plants will greatly expand the use of this environmentally friendly, sustainable source of electric power for industry and communities worldwide.

Biomass-fueled power plants have been serving industry for many years, and providing 24 hour-per-day year-round on-site power in many areas of the world. However, their efficiency is low relative to what could be done with new technological advances, and their use has been limited relative to the biomass resources available for fuel. Most of these power plants have been placed in service by the wood products industry where large quantities of fairly clean woodwaste are available for use as fuel to fire boilers. Sugarcane mills have also been fairly large users of biomass, in their case bagasse, to fire boilers.

Most of the bagasse-fueled power plants are very inefficient at generating electric power which in the past was not of major concern; however, due to increased demand for electric power in the areas growing sugarcane and the pressure on mills to increase their energy efficiency, this is no longer acceptable. Used under sustainable management practices, biomass such as sugarcane leaves and trash, rice hulls, animal manure, cotton gin trash, cotton stalks, corn stalks, straws, and grasses are viable sources of biomass for fueling power plants but generally are not used due to technological limitations. There is great opportunity to increase the efficiency of generating electrical power from currently used biomass fuel sources and great opportunity to expand the types of biomass that could be used as fuel for generating electrical power. Increased efficiency and greater fuel flexibility will allow users to take advantage of the many benefits of biomass-derived electric power.

Increasing the efficiency of generating electrical power from biomass over that currently available and increasing the type and amount of biomass fuels suitable for use in biomass power plants, all at an economically competitive price, will require a new generation of power plant that exploits recent advancements in several areas of technology.

A very promising technological path for increasing the efficiency of biomass power plants and greatly expanding the types of biomass that can be use as fuel is a properly designed biomass-fueled integrated-gasifier gas turbine (BIGGT) power plant. Figure 1 is a BIGGT power plant block flow diagram. This paper will briefly present the market requirements, the technology to meet the requirements, a power plant design, and a projected financial analysis of this type of power plant.

Market Requirements

There is a need in the worldwide market for biomass power plants with the following characteristics:

- Size in units from 1 to 20 MWe.
- Capable of using a large variety of biomass fuels without extensive preprocessing.
- Simple, reliable, durable, and easily maintained.
- Minimal initial capital cost, low operating cost, and (therefore) minimal cost of electricity.
- Ash byproduct, no wastewater to treat.
- Exhaust gases meeting all air quality requirements.
- Readily available and affordable parts and service.

Technology To Meet The Market Requirements

The Cratech biomass power plant is being developed to meet these requirements by integrating a gasifier with a gas turbine engine. The BIGGT system envisioned by Cratech is shown by the schematic in Figure 2. Strictly from an academic point of view, this is not the simplest of cycles nor the most efficient; however, given the numerous tradeoffs that a design engineer must consider while at the same time boldly meeting the market requirements, the BIGGT power system is considered to have great potential to succeed in the market.

It is possible that, in the future, integrating a gasifier with a fuel cell can compete with this system. Fuel cells can approach 50% simple cycle efficiency which is higher than the simple cycle efficiency of gas turbines especially in small sizes. But the current cost of fuel cells greatly outweighs their advantage in efficiency. Gas turbine engines on the other hand have greatly improved in thermal efficiency during the past 15 years, and their share of the

cost of producing electricity is gradually dropping. This trend will probably continue. Until the cost-to-benefit ratio of the fuel cell is favorable with that of the gas turbine engine, the more competitive system for serving the biomass power industry in the foreseeable future is the BIGGT.

Power Plant Design

Several technical challenges must be overcome before economical small scale BIGGT power plants become a commercial reality; however, much progress towards this goal has been made during the past few years. The following is a brief discussion of some major features of the Cratech system that are being developed to commercialize this type of power plant and meet the market requirements. A system schematic is shown in Figure 2.

Bulk Biomass Feed System

This system is the initial feeding point for the biomass. The feed hoppers have live bottoms capable of feeding most types of biomass. The biomass is fed to a size reduction hammermill if required. The amount of size reduction should be kept to a minimum. Size reduction will not be required for such feedstocks as sawdust, rice hulls, cotton gin trash, nut shells, and bagasse. It would be required for large wood chips. If moisture content is greater than 20%, drying will be a benefit; otherwise no drying is required. The biomass is then pneumatically conveyed to the high pressure feed vessel.

Biomass Pressurization and Meter Vessels

The components of this system are critical, as they answer the question: How do you economically feed bulky biomass into a pressure vessel? The major disadvantage of the BIGGT concept over other biomass-to-electricity generating concepts (that do not require feeding biomass under pressure) is this problem. A considerable amount of thought has been put into the design of the biomass pressurization vessel. Its outstanding features are its small valves for the biomass inlet and outlet and its large storage volume required to minimize valve cycle times. This component together with the meter vessel will provide a durable system for accurately and reliably feeding all types of bulky biomass to the pressurized reactor vessel.

Pressurized Reactor Vessel

A small scale biomass power plant needs to be very fuel flexible because there is little margin to allow for hardware customization. As a result, the fluidized bed reactor has been chosen as the heart of the gasification system because it will operate under full control with almost any type of biomass with minimal preprocessing. There are many advantages of pressurized gasification, one of them being that the produced fuel gas can be fed to the gas turbine without further compression.

Hot Gas Cleanup

The gas exiting the reactor is thoroughly cleaned of particles that would be damaging to the turbine. The BIGGT system removes the particles under hot dry conditions using a single stage cyclone followed by a hot gas filter vessel. This cleaning process has three advantages over other types of processes: 1) no heat exchangers are needed, 2) no scrubbing is required nor wastewater to treat, and 3) the sensible heat of the gas is retained. The gas cleaning system was tested during phase 1 work and found to clean the gas such that the particulate concentration of the gas entering the first stage turbine rotor would be 1 ppm or less with no particle larger than 2.8 um. This meets gas turbine cleanliness requirements [1,2].

Gas Turbine Engine

The gas turbine engine is ideal for integrating with a pressurized gasification system. It is a fairly simple heat engine that can burn the type of low heat value gas that is produced and benefits from enormous development efforts during the past few years. Its simple cycle efficiency is gradually increasing, and its share of the cost of electricity is dropping. For stationary power sources now and especially in the future this is the best choice of the prime mover.

Current State Of Development

Cratech is progressing with a three-phase plan to develop this power plant for commercial use. These phases are:

Phase 1: Feed rate of 0.5 mtph (metric ton per hour) at 2 atmospheres pressure, including a slipstream flow hot gas cleanup system.

Phase 2: Feed rate of 1 mtph at 10 atmospheres pressure, including a full flow hot gas cleanup system.

Phase 3: Integrating the phase 2 system with a 1 MWe gas turbine engine generator set.

Phase 1 of this development program is complete. Figure 3 is a gasifier system performance chart of a typical phase 1 run. A summary of the phase 1 work has been reported [3]. Phase 2 is now under way.

Financial Analysis

The expected cost of power resulting from placing this type of biomass power plant in service is very difficult to estimate without specifying a site (i.e., generically sited). Numerous factors come into play at any given site; however, the best way to present this estimate to a large variety of interested readers is generically sited. Figures 4 and 5 give the basic assumptions, a schematic, and a financial analysis for two power plant sizes. The smaller power plant might be sited where the biomass is already on-site. This could be a small industrial facility (perhaps a small rice mill or sawmill) with a zero or negative value biomass waste stream. The larger power plant would be suitable as a cogeneration or combined cycle power plant for a sugarcane mill, ethanol plant, or perhaps even a stand-alone community electric power plant. The financial assumptions will vary widely. The assumptions chosen generally reflect those expected to be found in the current finance market.

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assistance from the Tennessee Valley Authority and The State of Vermont Department of Public Service.

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Figure 1. BIGGT power plant block flow diagram

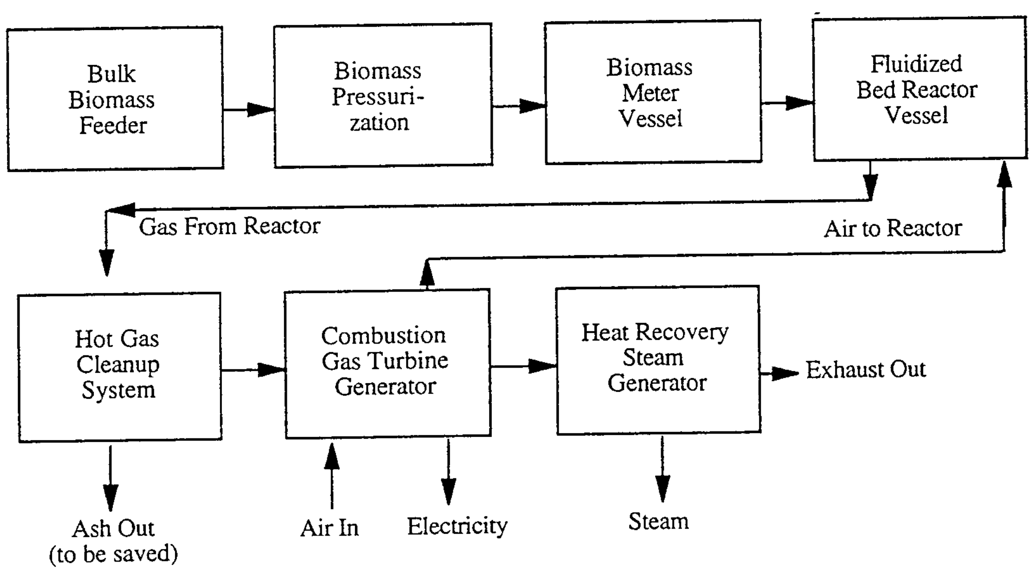


Figure 2. Cratech BIGGT power plant schematic

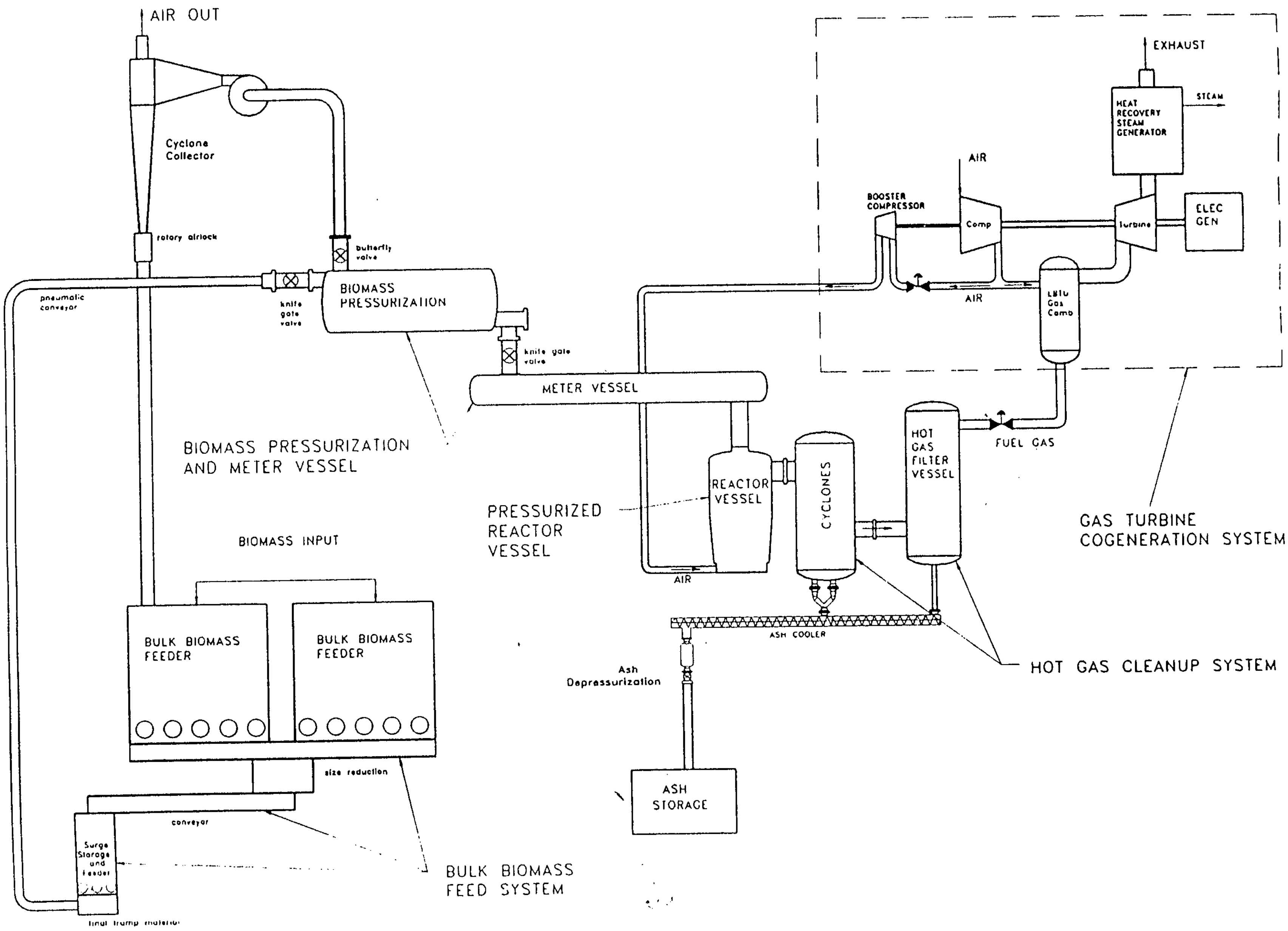


Figure 3. Phase 1 gasification system performance

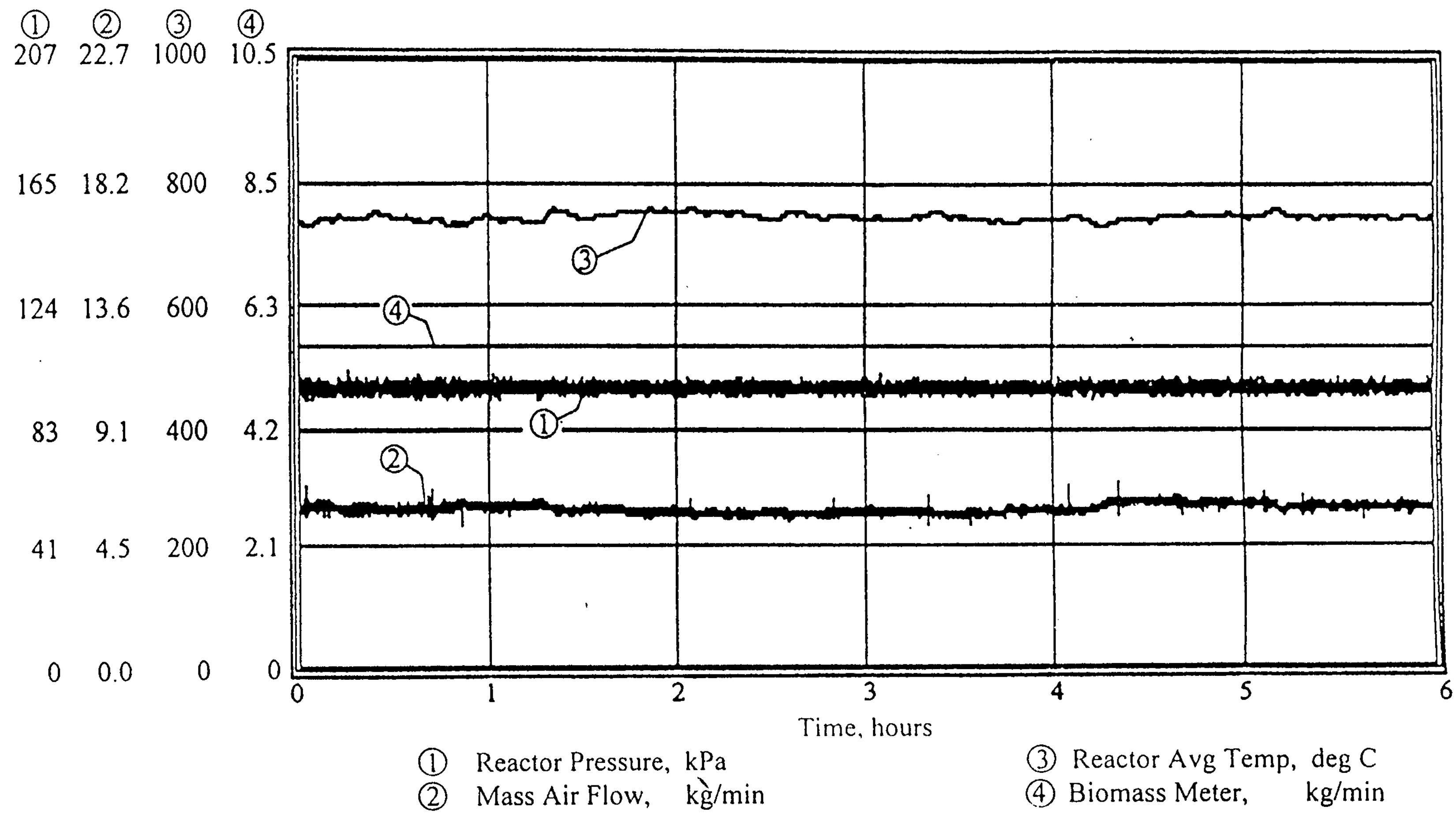


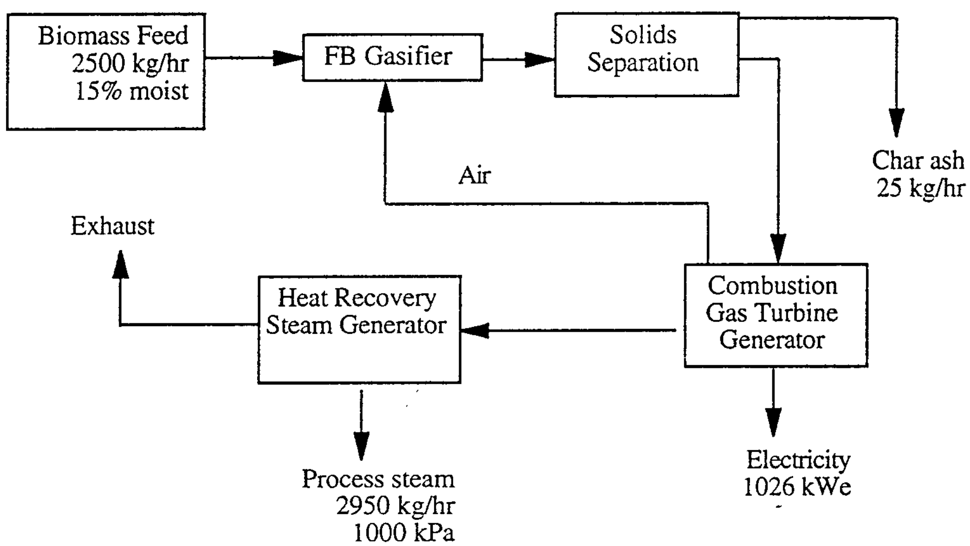
Figure 4: Financial analysis of a 1 MWe generically sited BIGGT power plant

Basic Assumptions

Finance:
- Total Investment: $2.19 million
- Down Payment: $657,000
- Term of Loan: 10 years
- Interest Rate: 8.5%
- Salvage Value: 20% (at end of 10 yrs)
- Turnkey price not including taxes or building to house plant

Production Costs:
- Biomass Fuel: $0/ton
- Hours Operation: 8040 hrs/yr
- Part-Time Operator: $10/hr (one per shift)
- Maintenance: $0.01/kWh
- Insurance: $30,450/yr
- Admin, legal: $5,000/yr

Schematic of Power Plant



Financial Analysis Result

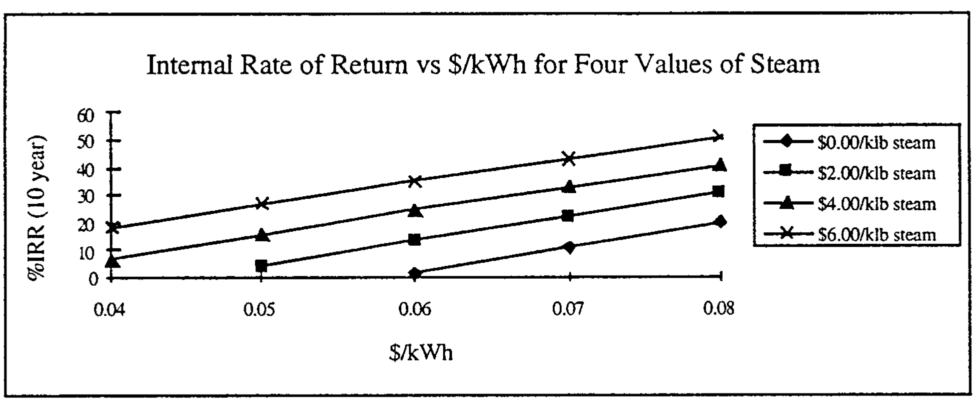


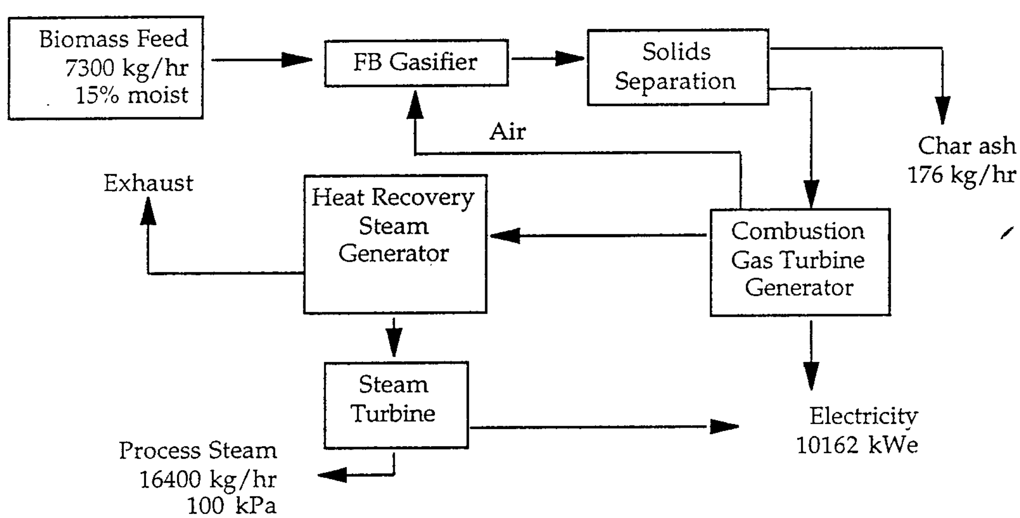
Figure 5. Financial analysis of a 10 MWE generically sited BIGGT power plant

Basic Assumptions

Finance:
- Total Investment: $16.3 million
- Down Payment: $4.9 million
- Term of Loan: 10 yrs
- Interest Rate: 8.5%
- Salvage Value: 20%
  (at end of 10 yrs)
  Turnkey price not including taxes or building to house plant

Production Costs
- Biomass Fuel: $5/ton
- Operation: 8040 hrs/yr
- Operator: $30/hr
  (one per shift)
- Maintenance: $0.01/kWh
- Insurance: $225,750/yr
- Admin, legal: $20,000/yr

Schematic of Power Plant



Financial Analysis Result